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COVER SHEET FOR TECHNICAL MEMORANDUM

TITLE- Potential Requirements for Apollo Crew Alternate Oxygen System

TM- 67-2031-3

DATE- September 30, 1967

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AUTHOR(S)- R. D. Raymond

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Life Support
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ABSTRACT

The potential contingencies requiring a capability for alternate systems for supplying breathing oxygen are defined for each phase of the mission starting with either air or oxygen at launch. These contingencies may require an alternate oxygen system, e.g., a mask or separate suit or helmet connection. The atmosphere related contingencies examined include such problems as suit loop failures with air in the cabin, cabin contamination during shirtsleeve operations and emergency egress on the pad. The oxygen system functions required to counter these contingencies are presented and the principal constraints limiting system design possibilities are summarized. These requirements are then compared with the capabilities planned for the CSM when modified for use of air on the pad. It is noted that many functions suggested are incorporated in already planned emergency oxygen supply components. However, to implement some additional functions will require more equipment, e.g., a direct alternate oxygen connection to the suit.

It is concluded that no matter whether air or oxygen is used at launch a need exists for an alternate oxygen system. Ideally, the system should be usable by the crew in all mission phases. It appears that this would require a mask for out-of-suit use and a direct suit connection for in-suit use. In addition, a separate, relatively short term supply of gaseous oxygen with a recharge capability from the cryogenic supply would be desirable as the alternate oxygen source.

[redacted] (ACCESSION NUMBER) (THRU) [redacted]

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BA-146 (8-64)

Abstract (Contd.)

To improve the margin of crew-safety the alternate oxygen system should be effective against contamination, low partial oxygen pressure, low total pressure, and single or multiple environmental control system malfunctions (e.g., suit loop or both cabin and suit loop malfunctions) for most crew and spacecraft configurations throughout the nominal mission and abort regimes. The alternate oxygen system should supplement the cabin atmosphere and suit loop systems during contingencies, not substitute for these systems in the nominal case.

The addition of supplemental gaseous oxygen, independently controlled suit oxygen lines (for use with helmets and suits on) and face masks (for use with helmets off) can provide significant safety improvement over the basic environmental control system cabin atmosphere and suit loop.

BELLCOMM, INC.
1100 Seventeenth Street, N.W. Washington, D.C. 20036

SUBJECT: Potential Requirements for Apollo Crew Alternate Oxygen System Case 330

DATE: September 30, 1967

FROM: R. D. Raymond

TM -67-2031-3

TECHNICAL MEMORANDUM

INTRODUCTION

The Apollo Environmental Control System (ECS) supports the physiological needs of the crew adequately for most contingencies when oxygen is used as a pressurant. However, changes are being made in the spacecraft to enable either air or oxygen to be used as a cabin pressurant on the pad. Therefore, a review of the crew requirements specifically for breathing oxygen in each mission phase was performed without limiting the evaluation by approved hardware changes. This study examines the need for alternate oxygen supply functions if either air or oxygen is used at launch.

The most significant requirements for an alternate oxygen system were compared with the capabilities expected to be provided by changes planned in the CSM ECS to enable use of air on the pad as an option and concurrent related changes to incorporate oxygen masks and rapid repressurization. This comparison focuses attention on a few additional significant equipment capabilities that should be considered for inclusion in the planned spacecraft modifications.

SYSTEM DISCUSSION

The Apollo system is required to provide support for crew physiological functions including respiration, body pressure and thermal conditioning.(1) The existing Environmental Control System (ECS) provides the necessary functions in the nominal case and for the majority of contingencies. In the spacecraft the functions are accomplished with the use of a gaseous medium (oxygen) supplied in flight from a primary cryogenic oxygen source in the SM or from secondary gaseous oxygen containers that are resupplied from the primary source.

Two ECS gaseous environment control methods, cabin atmosphere system (or cabin) and pressure garment system (or suit loop), are used concurrently or alternately to provide maximum crew safety consistent with operational requirements, e.g., shirtsleeve operation, crew transfer, etc. These two systems are not completely separated (since they have a common supply and some common lines and controls) but they can be effectively isolated at the independent pressure regulators.

This study of an alternate oxygen system is primarily concerned with the supply of the proper composition of breathing oxygen rather than maintenance of suit or cabin total pressure. In only a few instances can suit or cabin total pressure be reasonably supplemented, e.g., by direct oxygen input to a donned suit when cabin pressure is low. Furthermore, little additional body temperature control is available as a byproduct of a simple alternate oxygen supply method. Therefore, this discussion is essentially limited to the maintenance of a viable respiration alternative (i.e., sufficient oxygen partial pressure, adequate total pressure if possible and sufficiently low contamination levels).

The astronauts are provided breathing oxygen on a mission by either a primary or a backup system under nominal conditions. The suit loop is the primary supply with suits and helmets donned, backed up by cabin atmosphere. With suits or helmets doffed the same systems are active, except the cabin atmosphere is primary and the suit loop is backup. The ECS also operates in both modes to provide for some crewmen in suits while others are in shirtsleeves. This system arrangement accommodates the crew oxygen needs in the nominal and most single failure contingency situations. However, it is possible to encounter contingencies for which neither the cabin atmosphere nor the suit loop will sustain the crew.

POSSIBLE CONTINGENCIES

The lunar mission phases were examined for atmosphere related contingencies in order to derive requirements for an alternate oxygen supply that can adequately supplement existing capabilities.(1)(2) It is assumed that the spacecraft is redesigned to use either oxygen or air as a countdown cabin pressurant and oxygen after ascent.(1) Therefore, contingencies are included based on the use of air, as well as oxygen, at launch.

Many of the contingencies considered are or appear to be double malfunctions because the ECS normally provides two modes (suit and cabin) that must both be out of commission or inaccessible before an alternate is needed. However, these contingencies must be considered because one incident, e.g., smoke, can invalidate both ECS modes; one mode could be inaccessible during failure of the other; one mode may not be adequately provided 100 percent of the time; and, less significantly, two independent failures could occur.

The major mission phases and a composite of the contingencies examined are listed below. The detailed breakdown of contingencies as developed by mission phase is given in Appendix A. Contingencies listed are only those that could be countered by appropriate application of an alternate breathing source and are not now adequately covered by the functional capability of the existing ECS:

1. Mission Phases

   a. Countdown - During countdown failure or compromise of both the suit loop and cabin atmosphere could occur;

   b. Launch and Ascent - During ascent the cabin pressure is reduced to the extent that if air is used the cabin atmosphere does not provide adequate backup.(1)(3) In addition, the boost acceleration force complicates the removal of suit helmets or initiation of operation or manipulation of any alternate systems;

   c. In Transit (Suits Pressurized) - This condition exists after ascent until initial suit doffing and during all subsequent Service Propulsion System (SPS) burns in translunar, lunar and transearth trajectories;

   d. In Transit (Suits Unpressurized) - Most of the transit time is spent in this condition (suits doffed or helmet removed) using cabin atmosphere as the primary source of oxygen. This condition also applies to CSM solo orbit after LM descent. Suits are to be donned and pressurized in event of cabin depressurization or contamination. Time critical contingencies could require an alternate rapidly accessible oxygen supply, e.g., face masks;

   e. Crew Transfer - Intra-vehicular transfer is accomplished in pressurized suits with the aid of a long umbilical supplied by the CSM ECS. EVA transfer, if required, is accomplished with the aid of the portable life support system (PLSS) or the oxygen purge system (OPS);

f. LM Descent or Ascent - Suits and cabin are normally both pressurized. Both must become nonviable before an alternate oxygen source would be required;

g. Lunar Surface Stay - Normal life support conditions include pressure suits backed by cabin atmosphere, cabin atmosphere backed by suits (helmets doffed), pressure suits in depressurized cabin and pressure suits in EVA mode using PLSS;

h. Entry and Landing - During normal entry, pressure suits are donned and the cabin is pressurized. The cabin pressure increases as air flows in from the external ambient atmosphere. Entry acceleration loads are high, complicating manipulation of alternate systems;

i. Post Landing to Recovery - Normally the air intake and circulation system will supply fresh air to the cabin and suits can be doffed.

2. Contingencies

a. Fire and smoke in cabin and suit loop;

b. Leakage of volatile liquid or toxic gas or particles in the cabin and suit loop;

c. Fire in the cabin and suit disconnected for emergency egress.

d. Fire and smoke in cabin;

e. Leakage of volatile liquid or toxic gas in cabin;

f. Cabin pressure decrease to the extent that partial pressure of oxygen is low (assumes some dilution of cabin oxygen);

g. Suit loop contamination (not pressure loss) and cabin pressure loss;

h. Suit loop malfunction and cabin partial pressure of oxygen low (any single failure mode if air is used in the cabin and pressure has dropped during ascent);

i. Suit loop malfunction and cabin contaminated or partial pressure of oxygen low (with either air or oxygen in the cabin);

j. Intra-vehicular umbilical problems, e.g., the single long umbilical fails, is not accessible in LM or the umbilical connectors fail on suits or spacecraft;

k. Suit loop malfunction while transferring through tunnel;

l. EVA, PLSS and OPS oxygen supply exhaustion or malfunction or umbilical malfunction;

m. Cabin and suit loop contamination from air intake;

n. Air intake malfunction, or under water, and suit loop malfunction or entry oxygen exhausted.

FUNCTIONAL REQUIREMENTS AND DESIGN CONSTRAINTS

To be most effective the alternate oxygen system provided should accommodate all of the contingencies noted in the preceding paragraphs. However, the complexity of a system with the capability to perform all relevant functions may not be acceptable. This suggests that some functions that would be necessary only for the least significant contingencies, e.g., double independent malfunctions, be either omitted or satisfied by some provision other than a separate oxygen system.

Of the many contingencies presented for which an alternate oxygen system would be useful, the more significant result in the following conditions:

1. Contaminated Cabin Atmosphere - Contamination in the cabin when in shirtsleeve or helmet-off posture could result from fire, smoke, leakage, filter malfunction, etc. This situation could require equipment such as a separate oxygen source and a face mask. The condition is essentially independent of the type of cabin pressurant.

2. Contaminated Cabin Atmosphere and Suit Loop Problem - Contamination in the cabin when the suit is on, accompanied by a suit loop problem, e.g., malfunction, contamination or disconnected for egress, could result from fire, smoke, leakage, filter malfunction, etc. This situation could require equipment such as a separate oxygen source and face mask (for use if helmet can be removed) or a direct oxygen purge line to the helmet or suit (for use if the helmet cannot be removed). The condition is essentially independent of the type of cabin pressurant and can occur in flight or on the pad.

3. <u>Low Partial Pressure of Cabin Oxygen</u> - Low partial pressure of cabin oxygen when the suit is on could occur with a mixed gas, e.g., air on the pad, system at normal flight pressure. A low partial pressure and a suit loop malfunction or contamination contingency could support the addition of equipment such as separate oxygen source and face mask or direct line to the suit or helmet. This condition is more likely to occur with the use of air at launch than with oxygen.

4. <u>Low Total Pressure of Cabin Atmosphere</u> - Loss or lowering of the cabin total pressure accompanied by a suit problem when the suit is on could result from cabin leakage or poor regulation and a suit loop malfunction or contamination. This situation could require equipment such as a separate oxygen source and a direct line to the suit to provide both pressure and oxygen after isolation of the suit from the ECS suit loop.

Based on the contingency situations deemed most prevalent it appears that the following <u>functional requirements</u> are necessary for a satisfactory alternate oxygen system:

1. <u>Provide Oxygen (Suits Off)</u> - When the total pressure is sufficient but the atmosphere composition is not adequate and the suits or helmets are off, a means of providing oxygen to the crew is required, e.g., a face mask and separate oxygen tanks.

2. <u>Provide Oxygen (Suits On)</u> - When the total pressure is sufficient but the atmosphere composition is not adequate and the suits are on, a means of providing oxygen to the crew is required, e.g., a direct line to the suit or helmet and separate oxygen tanks.

3. <u>Provide Oxygen and Pressure (Suits On)</u> - When neither the total pressure nor the atmosphere composition are adequate and the suits are on, a means of providing oxygen and adequate total pressure is required, e.g., a direct line to the suit and separate oxygen tanks.

The principal unique design <u>constraints</u> limiting the design possibilities for an alternate oxygen system are summarized below. More general constraints, e.g., need for voice communication, are not itemized here. These constraints are based on the nominal lunar mission functions, abort functions related to environmental control and existing equipment design characteristics considered to be limiting, i.e., unchangeable.

1. Rapid Operation - The system must be capable of rapid, i.e., within seconds, initiation of operation immediately after a contingency is detected;

2. Operable Under "g-loads" - The system must be operable, including any manual operations, in varying acceleration regions including launch and ascent accelerations from 1 to 5g, abort loads of about 8 to 14 g, zero g, and entry loads of about 10g.[4]

3. Suits On or Off - The system must be usable with suits donned, suits doffed or only helmets doffed, and shall enable transition from suits doffed to suits donned. The system must also function in combinations of these configurations since all crew members may not be in the same configuration at once, e.g., when changing suits or preparing for EVA or crew transfer.

4. Short Term Supply - The system must be capable of providing a short term independent supply of gaseous oxygen for rapid emergency use. The tank or tanks should be rechargeable during and between uses from the CSM ECS cryogenic supply to convert the system to a longer term capability as required. The tank sizing criteria must consider the operational time needed to circumvent emergencies by achieving a safe posture, completing abort, performing pad egress, fighting fires, donning suits, etc. In addition, design constraints, e.g., weight, volume and portability, affect the sizing tradeoff to the extent that a feasible short term gaseous supply will probably be limited to less than one hour capability.

5. Eye Protection - The system should protect the eyes from contaminants while supplying oxygen for breathing via masks or suit/helmet connections.

6. Flexible Usage - The system should accommodate one, two or three crewmen in the CM; one or two crewmen in the LM or transferring between spacecraft; and one or two crewmen in EVA gear.

7. Portable - Since the system may be required in mobile situations, e.g., pad egress, EVA, and crew transfer, portability must be considered.

EQUIPMENT CAPABILITIES

The basic ECS system plus the currently planned changes will not provide the capability for all functions suggested in the preceding section. A comparision of alternate oxygen system requirements and the capabilities of the ECS with planned changes is made in Table 1. Examination of functions not provided for indicates the need for additional equipment as listed under additional modification needed.

For the purpose of the comparison the following capabilities are assumed for currently planned changes:[1]

1. Air or oxygen can be used in the cabin on the pad with 100 percent oxygen in the suit loop at a pressure slightly above cabin pressure;

2. Rapid cabin repressurization capability in flight by using additional gaseous oxygen tanks that can be refilled by the cryogenic system;

3. Emergency oxygen mask breathing system is provided for use should a fire be encountered in flight to provide sufficient time to permit the crew to extinguish the fire and don their space suits. (Oxygen is to be available from repressurization gas bottles at 100 psi at the mask connection interface.)

As shown in Table 1, the principal need for more equipment is to satisfy a requirement for an alternate source of oxygen when suits are on. This requires a separate connection to the suits from an independent oxygen supply. Oxygen masks as planned for the CM for use in event of a fire during shirtsleeve operation may suffice for all CM mask needs. It should be noted that the oxygen tanks sized for rapid repressurization may not adequately provide the flexibility needed to supply the masks and a direct suit input.

The potential requirement for more equipment in the LM, as indicated in Table 1, is based on contingencies for LM active phases of the mission. As shown in Appendix A, during crew transfer and LM descent or ascent the crewmen remain suited and can find use for a direct oxygen input to the suit or helmet. During lunar surface stay the helmets may be doffed while in a pressurized LM, presenting the possibility of needing a mask in case of fire or contamination contingencies. However, if the helmet can be donned as rapidly as a mask, the need for a mask is reduced. Further consideration is needed to make this tradeoff. Other situations exist in LM that are similar to those in the CM that could require masks or direct suit input lines for the CM. Therefore, the LM could usefully employ the type of alternate oxygen system components provided for the CM. The necessity for (or overall cost effectiveness of) additional equipment in the LM may not be as great as for the CM because of reduced stresses, e.g., acceleration and operating time, but the need could exist if the listed contingencies occur.

CONCLUSION

An evaluation of the possible contingencies that might occur in various mission phases indicates that a significant improvement in crew safety can be achieved by adding an alternate oxygen system. This system can best be used in the form of an oxygen mask for contingencies including fire and contamination or low oxygen partial pressure when suits or helmets are off. For periods when helmets cannot be rapidly doffed (e.g., pad egress, ascent, abort, EVA or entry) the system should be preconnected to the suits or helmets and should be automatically activated or easily manipulated. The system should include a short term separate supply of oxygen and be usable in the CM or LM and possibly during EVA. The system should be compatible with limited manual operations achievable under the potential adverse conditions, e.g., high acceleration or busy timeline, existent at the time of emergency. The alternate breathing system should be provided primarily for contingency use and should not substitute for the existing ECS cabin atmosphere and suit loop systems during normal operation.

Comparing the requirements with anticipated capability (including the currently planned changes for oxygen masks, rapid repressurization and capability for air in the cabin on the pad) indicates a need for some additional modification. In particular, new provisions are needed for direct oxygen supply to the suit and more flexibility for emergency use of an alternate oxygen system in the LM as well as in the CM.

2031-RDR-jcd

R D Raymond

R. D. Raymond

Attachments
Appendix A
Tables 1 and A-1

TABLE 1. COMPARISON OF REQUIREMENTS AND CAPABILITIES

FUNCTION	DESIGN CONSTRAINTS	PLANNED MODIFICATION	ADDITIONAL MODIFICATION NEEDED
PROVIDE OXYGEN (SUITS ON)	1. RAPID OPERATION 2. G-LOADS 3. SUITS ON 4. SHORT TERM 5. EYE PROTECTION 6. FLEXIBLE USAGE 7. PORTABLE	NONE*	1. DIRECT OXYGEN LINE TO HELMET OR SUIT 2. OXYGEN TANKS FOR USE IN CM AND LM
PROVIDE OXYGEN (SUITS OFF)	1. RAPID OPERATION 2. G-LOADS 3. SUITS OFF 4. SHORT TERM 5. EYE PROTECTION 6. FLEXIBLE USAGE 7. PORTABLE	1. OXYGEN MASKS FOR SHIRTSLEEVE USE IN CM 2. EXTRA OXYGEN FROM TANKS PROVIDED FOR RAPID CABIN REPRESSURIZATION & LINE FOR MASKS	1. OXYGEN MASKS FOR USE IN LM 2. SEPARATE OXYGEN TANKS IN LM 3. DIRECT CONNECTION FROM EXTRA OXYGEN TANKS TO MASKS (LM AS WELL AS CM)
PROVIDE OXYGEN AND PRESSURE (SUITS ON)	1. RAPID OPERATION 2. G-LOADS 3. SUITS ON 4. SHORT TERM 5. EYE PROTECTION 6. FLEXIBLE USAGE 7. PORTABLE	NONE*	1. DIRECT OXYGEN LINE TO HELMET OR SUIT 2. OXYGEN TANKS FOR USE IN CM AND LM

*EXCEPT FOR REVISION OF THE DIRECT OXYGEN FLOW LINE INTO THE SUIT LOOP TO PROVIDE BETTER CONTROL FOR KEEPING THE SUIT PRESSURE ABOVE CABIN PRESSURE WITH AIR IN THE CABIN.

REFERENCES

1. NASA Apollo Program Working Paper No. 1221, Environmental Control System, MSC, Houston, Texas, April 3, 1967.

2. MSC Report No. PM3/M-171/66, Design Reference Mission IIA, MSC, Houston, Texas, October 30, 1966.

3. Bottomley, T. A., Jr., Physiological Constraints Air-on-the-Pad, TM-67-2031-4, Bellcomm, Inc., September 30, 1967.

4. MSC Internal Note No. 66-FM-149, Spacecraft Operational Abort and Alternate Mission Plan for AS-501, Volume 1 - Abort Plan, MSC, Houston, Texas, December 22, 1966.

APPENDIX A

CONTINGENCIES DERIVED BY MISSION PHASE

The possible contingencies examined are listed below by significant mission phase[1] and are summarized in Table A-1. Contingencies listed are only those that could be countered by appropriate application of an alternate breathing source and are not now adequately covered by the functional capability of the existing ECS:

1. Countdown - During countdown the failure or compromise of both the suit loop and cabin atmosphere by:

   a. Fire and smoke in cabin and suit loop;

   b. Leakage of volatile liquid or toxic gas or particles in the cabin and suit loop;

   c. Fire in the cabin and suit disconnected for emergency egress.

2. Launch and Ascent - During ascent the cabin pressure is reduced to the extent that if air is used the cabin atmosphere does not provide adequate backup.[1][3] In addition, boost acceleration force complicates the initiation of operation or manipulation of any alternate systems. These contingencies may be encountered:

   a. Fire and smoke in cabin and suit loop;

   b. Leakage of volatile liquid or toxic gas or particles in the cabin and suit loop;

   c. Suit loop contamination (not pressure loss) and cabin pressure loss;

   d. Suit loop malfunction and cabin partial pressure of oxygen low (any single failure mode if air is used in the cabin and pressure has dropped during ascent);

   e. Suit loop malfunction and cabin contaminated or partial pressure of oxygen low (with either air or oxygen in the cabin).

3. In Transit (Suits Pressurized) - This condition exists after ascent until initial suit doffing and during all

subsequent SPS burns in translunar, lunar and trans-earth trajectories. Possible contingencies include:

a. Fire and smoke in cabin and suit loop;

b. Leakage of volatile liquid or toxic gas or particles in the cabin and suit loop;

c. Suit loop contamination (not pressure loss) and cabin pressure loss;

d. Suit loop malfunction and cabin partial pressure of oxygen low (if air is used and not yet replaced with oxygen or cannot be replaced due to cabin dump failure);

e. Suit loop malfunction and cabin contaminated or partial pressure of oxygen low (with either air or oxygen in the cabin).

4. <u>In Transit (Suits Unpressurized)</u> - Most of the transit time is spent in this condition (suits doffed or helmet removed) using cabin atmosphere as the primary source of oxygen. This condition also applies to CSM solo orbit after LM descent. Suits are to be donned and pressurized in event of cabin depressurization or contamination. Time critical contingencies including the following could require an alternate rapidly accessible oxygen supply, e.g., face masks:

a. Fire and smoke in cabin;

b. Leakage of volatile liquid or toxic gas or particles in cabin;

c. Cabin pressure decrease to the extent that partial pressure of oxygen is low (assumes some dilution of cabin oxygen).

5. <u>Crew Transfer</u> - Intra-vehicular transfer is accomplished in pressurized suits with the aid of a long umbilical supplied by the CSM ECS. EVA transfer, if required, is accomplished with the aid of the PLSS or OPS. Contingencies for which a separate oxygen source could be useful include:

a. Fire and smoke in cabin and suit loop;

b. Leakage of volatile liquid or toxic gas or particles in cabin and suit loop;

c. Suit loop contamination (not pressure loss) and cabin pressure loss (including while cabin is depressurized for EVA);

d. Intra-vehicular umbilical problems, e.g., the single long umbilical fails, is not accessible in LM or the umbilical connectors fail on suits or spacecraft;

e. Suit loop malfunction while transferring through tunnel;

f. EVA, PLSS and OPS oxygen supply exhaustion or malfunction or umbilical malfunction.

6. <u>LM Descent or Ascent</u> - Suits and cabin are normally both pressurized. Both must become nonviable before an alternate oxygen source would be required. Possible contingencies are:

a. Fire and smoke in cabin and suit loop;

b. Leakage of volatile liquid or toxic gas or particles in cabin and suit loop;

c. Suit loop contamination (not pressure loss) and cabin pressure loss;

d. Suit loop malfunction and cabin contaminated or partial pressure of oxygen low.

7. <u>Lunar Surface Stay</u> - Normal life support conditions include pressure suits backed by cabin atmosphere, cabin atmosphere backed by suits (helmets doffed), pressure suits in depressurized cabin and pressure suits in EVA mode using PLSS. Possible contingencies include:

a. Fire and smoke in cabin and suit loop;

b. Leakage of volatile liquid or toxic gas or particles in cabin and suit loop;

c. Suit loop contamination (not pressure loss) and cabin pressure loss (including while cabin is depressurized for EVA);

d. Fire and smoke in cabin (when helmet is doffed);

e. Leakage of volatile liquid or toxic gas or particles in cabin (when helmet is doffed);

f. EVA, PLSS and OPS oxygen supply exhaustion or malfunction or umbilical malfunction.

8. Entry and Landing - During normal entry pressure suits are donned and the cabin is pressurized. The cabin pressure increases as air flows in from the external ambient atmosphere. Entry acceleration loads are high, complicating manipulation of alternate systems. Possible contingencies include:

   a. Fire and smoke in cabin and suit loop;

   b. Leakage of volatile liquid or toxic gas or particles in cabin and suit loop;

   c. Suit loop manfunction and cabin contaminated or partial pressure of oxygen low;

   d. Entry oxygen supply exhausted;

   e. Cabin and suit loop contamination from air intake.

9. Post Landing to Recovery - Normally the air intake and circulation system will supply fresh air to the cabin and suits can be doffed. Contingencies include:

   a. Fire and smoke in cabin;

   b. Leakage of volatile liquid or toxic gas or particles in cabin;

   c. Air intake malfunction, or under water, and suit loop malfunction or entry oxygen exhausted.

TABLE A-1 CONTINGENCIES AFFECTING NORMAL OXYGEN SYSTEM

POSSIBLE CONTINGENCIES REQUIRING ALTERNATE SYSTEM	ALTERNATE SYSTEM APPLICABLE DURING SIGNIFICANT MISSION PHASE*								
	COUNT-DOWN (1)	LAUNCH AND ASCENT (2)	IN TRANSIT (SUITS PRES-SURIZED) (3)	IN TRANSIT (SUIT UN-PRESSURIZED) (4)	CREW TRANSFER (5)	LM DESCENT OR ASCENT (6)	LUNAR SURFACE STAY (7)	ENTRY AND LANDING (8)	POST LANDING TO RE-COVERY (9)
FIRE AND SMOKE IN CABIN AND SUIT LOOP	YES (A)	YES (A)	YES (A)	NO	YES (A)	YES (A)	YES (A)	YES (A)	NO
LEAKAGE OF VOLATILE LIQUID OR TOXIC GAS, CABIN AND SUIT LOOP	YES (B)	YES (B)	YES (B)	NO	YES (B)	YES (B)	YES (B)	YES (B)	NO
SUIT LOOP CONTAMINATION (NOT PRESSURE LOSS) AND CABIN PRESSURE LOSS	NO	YES (C)	YES (C)	NO	YES (C)	YES (C)	YES (C)	NO	NO
SUIT LOOP MALFUNCTION WITH AIR IN CABIN (LOW PARTIAL O_2)	NO	YES (D)	YES (D)	NO	NO	NO	NO	NO	NO
SUIT LOOP MALFUNCTION AND CABIN CONTAMINATED OR PARTIAL PRESSURE O_2 LOW (AIR OR OXYGEN)	NO	YES (E)	YES (E)	NO	NO	YES (D)	NO	YES (C)	NO
FIRE AND SMOKE IN CABIN	YES (C)	NO	NO	YES (A)	NO	NO	YES (D)	NO	YES (A)
LEAKAGE OF VOLATILE LIQUID OR TOXIC GAS IN CABIN	NO	NO	NO	YES (B)	NO	NO	YES (E)	NO	YES (B)

*YES - INDICATES AN ALTERNATE BREATHING SYSTEM SHOULD BE CONSIDERED FOR STATED CONTINGENCY DURING THE APPLICABLE MISSION PHASE.

*NO - INDICATES THAT THE CONTINGENCY PROBABLY WILL NOT OCCUR IN THE SPECIFIC MISSION PHASE, THAT AN ALTERNATE BREATHING SYSTEM WILL NOT BE EFFECTIVE OR THAT A MORE APPROPRIATE CONTINGENCY LISTING IN THE TABLE COVERS THE SITUATION.

( ) - INDICATES REFERENCE TO ITEMS DESCRIBED IN TEXT UNDER <u>POSSIBLE CONTINGENCIES</u>.

TABLE A-1 (CONTINUED)

CABIN PRESSURE DECREASES SO PARTIAL PRESSURE OF O_2 IS LOW	NO	NO	NO	YES (C)	NO	NO	NO	NO	NO
LONG UMBILICAL PROBLEMS WHILE TRANSFERRING TO LM OR TO CM	NO	NO	NO	NO	YES (D)	NO	NO	NO	NO
SUIT LOOP MALFUNCTION WHILE TRANSFERRING THROUGH TUNNEL	NO	NO	NO	NO	YES (E)	NO	NO	NO	NO
EVA PLSS OR EOS FAILURE (EVA MODE)	NO	NO	NO	NO	YES (F)	NO	YES (F)	NO	NO
ENTRY OXYGEN SUPPLY EXHAUSTED	NO	NO	NO	NO	NO	NO	NO	YES (D)	NO
CABIN AND SUIT LOOP CONTAMINATION FROM AIR INTAKE	NO	NO	NO	NO	NO	NO	NO	YES (E)	NO
AIR INTAKE AND SUIT LOOP MAL-FUNCTION (OR ENTRY OXYGEN EXHAUSTED)	NO	NO	NO	NO	NO	NO	NO	NO	YES (C)